2015

University of Idaho

Senior Design Team “Three Phase”
Authored by: Jacob Nelson

[UNITROL-1020 DIGITAL SIMULATION MODEL GUIDE]

A guide to summarize how to use and implement the digital model for the Unitrol-1020 exciter. This manual includes verification steps taken to date.

Table of Contents

1 Introduction

In this manual it will discuss how to load, read, and use the digital model implemented by senior design group “Three Phase”. This manual will also address the limitations of the model, as of 4/29/2015, and explain what has been left for future projects to implement and verify.

The models and parameters used for the ST5C are directly from the ABB document ZAB-3BHS223093-E62-Rev. D which has been attached as an appendix. The model for the URTS5T is provided as a library function by RTDS Inc. “Three Phase” had no involvement in the development of either of the models or the parameters.

The ST5C model was compared to every library exciter model in RSCAD’s master library and the closest matching exciter that was found was the URTS5T model. To verify the ST5C model behaves as expected, the ST5C was compared to the URTS5T while each exciter was connected to an identical generator and dynamic load. The dynamic load had its reactive power varied and the response of the generator’s terminal voltage was inspected and compared.

2 Opening the Model

The model for the Unitrol-1020 and the generator are not saved as a library function. In order to load the model on a lab computer use the following information (shown in figure 1). (A copy of the model files are also saved to the USB attached to this folder.)

“RSCAD_USER” > 3phaseECE480 > ST5C Implement.dft

Use the copy function to copy the exciter into a new workspace so that the original file is not corrupted.

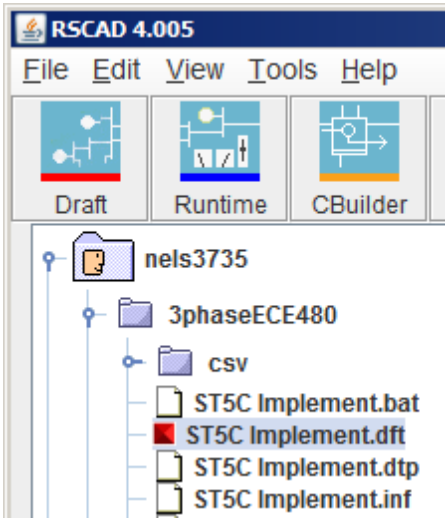

Figure 1: Loading Draft File From RSCAD Software

3 Model Details

Once the file has been opened, the exciter model can be viewed by double clicking on the grey box labeled “ST5C Digital Model”. The model has been subdivided to more closely resemble the ABB document and for ease of reading. The main page contains three main subdivisions that will be covered in the following sections.
To display the logic for the limiter functions, the user will need to click on the grey boxes inside of the ST5C Digital Model page. The limiters are listed below with their model status.

- Min Field Limiter – Completed
- Max Field Limiter – Completed
- Stator Limiter (min and max) – Completed
- V/Hz Limiter – No Model in RSCAD
- PQ Limiter – No Model in RSCAD
- PSS – No Model in RSCAD

3.1 Model Inputs

This section shows the enable/disable switches for individual limiters and features of the model. It also contains project specific inputs that are used to configure the various limiters that can be enabled for the Unitrol-1020 exciter.

3.2 Control Switches

PQ_enb – Enables the reactive power limiter.

VHz_enb – Enables the Volts per Hertz limiter.

IG_ind_enb – Enables the stator under-current limiter.

IG_cap_enb – Enables the stator over-current limiter.

IF_max_enb – Enables the field over-current limiter.

IF_min_enb – Enables the field under-current limiter.

PSS_enb – Enables **Power System Stabilizers.** (Disabled in model)

VCOMP – Selection of **Vectorial Compounding**,

SHUNT – Selection of **Shunt Supply**,

SES – Selection of **Static Excitation System**, changes between rotating and static excitation mode.
(Should always be a value of 1)

Vref – This slider allows the user to set the reference voltage of the generator's terminals (In a value of P.U.)

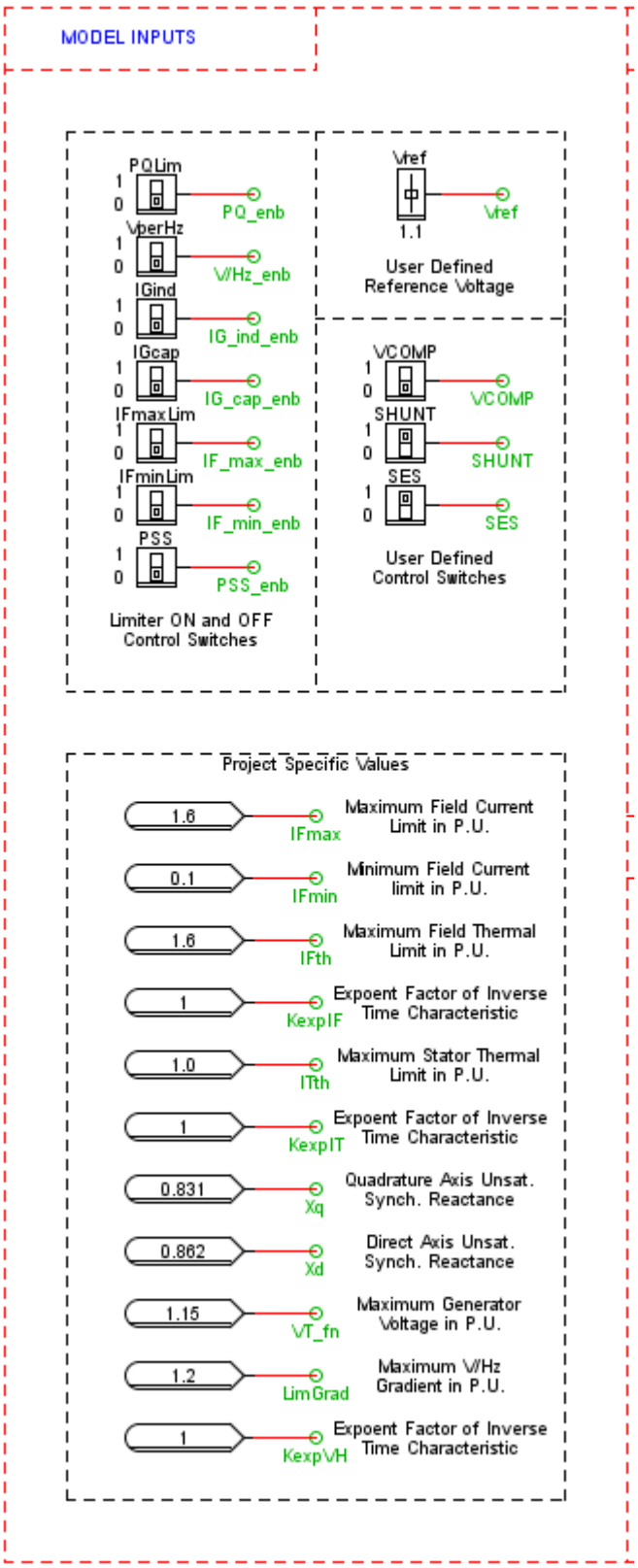

Figure 2: MODEL INPUTS box for RSCAD ST5C Representation

3.3 ST5C AVR Model

This section contains the AVR portion of the ST5C model. The output "VR" of this section is used in the "ST5C Supply Model" to calculate the final field voltage in per unit. The Power System Stabilizer (PSS) branch was included in this model for future use. Currently the PSS system model is force disabled. The min and max gates use a constant of -100 or 100 for each limiter unless it has been enabled by the switches in the "User Inputs" section.

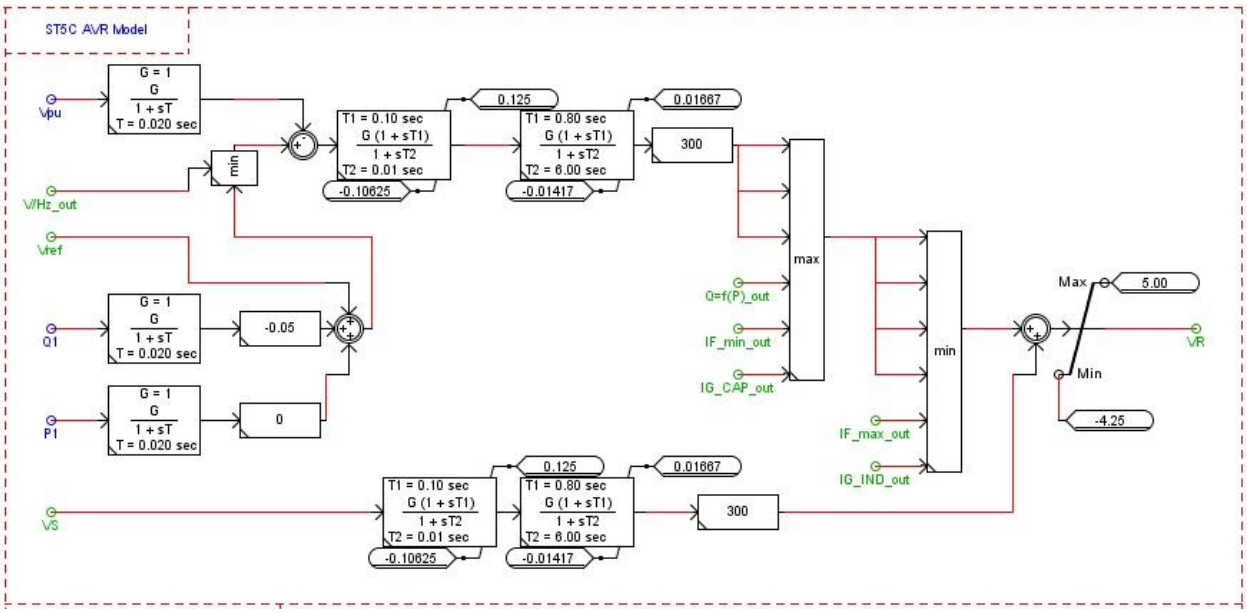

Figure 3: ST5C AVR Model in RSCAD

3.4 ST5C Supply Model

This section scales the output of the Voltage Regulator into the per unit value that will be used in the field of the generator. The "VR" signal is the output from the ST5C AVR model.

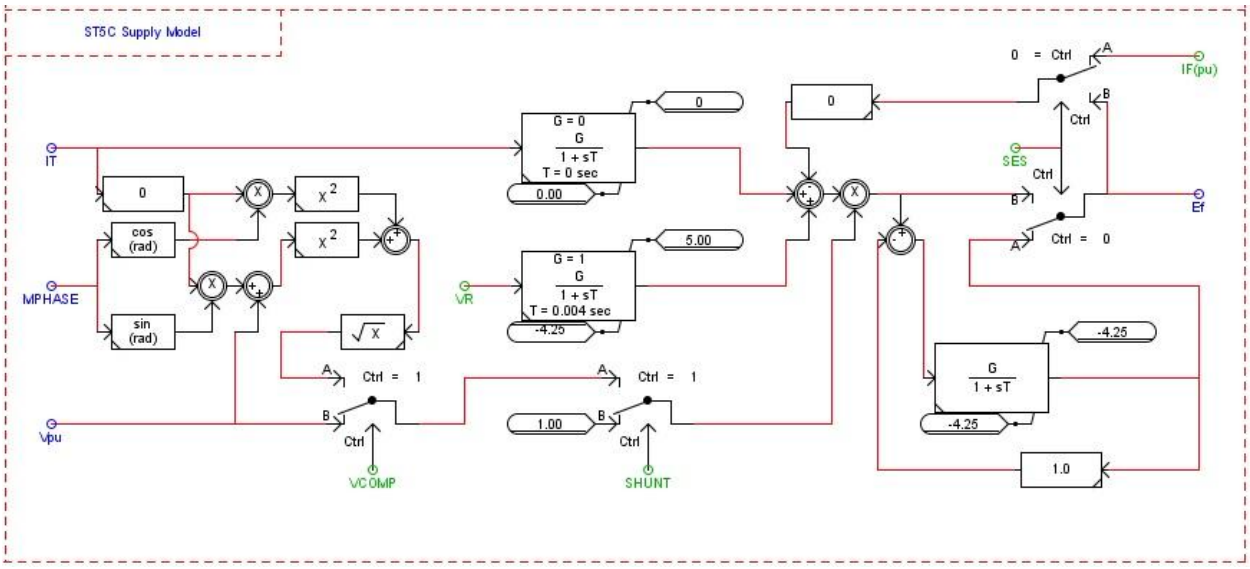

Figure 4: ST5C Supply Model in RSCAD

3.5 Specific Signal Names

In these models, many signal flags were made to connect the models. The following table shows the name of each signal, a description of what the signal is from, and if the signal is monitored by RUNTIME. Signals from the control switches are mentioned in section 4.2. Unless a value from this table is desired, the signals named in the table (left most column) should not be used in future expansions of this model.

Table 1: Signal Names Used in RSCAD Model

System Measurements	Signal Description	Units	Monitored label
Vpu	Terminal voltage of the generator	P.U.	Yes
Ef	Field voltage of the generator (exciter's output)	P.U.	Yes
IF(pu)	Field current of the generator	P.U.	NO
IT	Stator current of the generator	P.U.	Yes
MPHASE	Machine Phase angle (acosP.F.)	radians	Yes
P1	Real power output of the generator	MW	Yes
Q1	Reactive power output of the generator	MVAr	Yes
Limiting User Inputs			
IFmax	Maximum field current allowable	P.U.	NO
IFmin	Minimum field current allowable	P.U.	NO
IFth	Maximum thermal field current limit	P.U.	NO
ITth	Maximum thermal stator current limit	P.U.	NO
VT_fn	Maximum allowable generator voltage	P.U.	NO
LimGrad	Maximum V/Hz gradient	P.U.	NO
Generator Parameters			
Xd	Direct axis unsat. Synchronous reactance	P.U.	NO
Xq	Quadrature axis unsat. Synchronous reactance	P.U.	NO
Exponent Factors			
KexpIF	Expoent factor of inverse time characteristic	Unitless	NO
KexpIT	Expoent factor of inverse time characteristic	Unitless	NO
KexpVH	Expoent factor of inverse time characteristic	Unitless	NO

3.6 Gain and Time Constants

This section shows the time constants and gains used in the models featured in the above sections. The labels are the names that correspond to the ABB documentation. The default values were provided by ABB and need to be recalculated for our specific system (Section 1.3, 3.3, 3.6, 3.9, 4.3, 4.6, 4.9, 4.12, and 4.15 from the ABB document show the correspondence between model parameters and equipment settings).

Table 2: Time Constants from ABB Documentation

Label	Default	Units	Used in model
TR	0.020	S	AVR, PQ, IG, V/Hz, IFmax, IFmin,
TB11	6.00	S	AVR,
TC11	0.80	S	AVR,
TB21	0.10	S	AVR,
TC21	0.10	S	AVR,
Ts	0.004	S	Supply
TE	Not Used	S	Supply
KHVH	0	1/S	V/Hz,
KCVH	1000	1/S	V/Hz,
KToVH	1000	1/S	V/Hz,
KHF	0	1/S	IFmax,
KCF	1/150	1/S	IFmax,
KtoF	1/5	1/S	IFmax,
TB13	6.00	S	IFmax
TB23	0.10	S	IFmax
TC13	0.80	S	IFmax
TC23	0.10	S	IFmax
TB15	6.00	S	IFmin,
TB25	0.10	S	IFmin,
TC15	0.80	S	IFmin,
TC25	0.10	S	IFmin,
TB12	8.33	S	IG,
TB22	0.10	S	IG,
TC12	1.00	S	IG,
TC22	0.10	S	IG,
KHI	0	1/S	IG,
KCI	1/100	1/S	IG,
Ktol	1/5	1/S	IG,
TB14	15.00	S	IG,
TB24	0.10	S	IG,
TC14	0.10	S	IG,
TC24	0.10	S	IG,
TB16	15.00	S	PQ,
TB26	0.10	S	PQ,
TC16	1.00	S	PQ,
TC26	0.10	S	PQ,

Table 3: Gains from ABB Documentation

Label	Default	Units	Used in model
KR1	300	Unitless	AVR,
KR2	500	Unitless	IG,
KR3	300	Unitless	IFmax,
KR4	300	Unitless	IG,
KR5	300	Unitless	IFmin,
KR6	300	Unitless	PQ,
KIR	-0.05	Unitless	AVR,
KIA	0.00	Unitless	AVR,
KVC	0.00	Unitless	Supply,
KSC	0.00	Unitless	Supply
KID	0.00	Unitless	Supply,
KE	Not Used	Unitless	Supply,
LimGrad	1.2	Unitless	V/Hz,

4 URTS5T

The URTS5T is an IEEE standard model that is preset into RSCAD. Using the following assumptions, the ST5C model was compared to the URTS5T and determined to be (nearly) identical.

- VSIG is equivalent to VS (ST5C AVR) from PSS branch
- VUEL is equivalent to IFmin (ST5C AVR) from min field limiter
- VOEL is equivalent to IFmax (ST5C AVR) from max field Limiter
- QT + PT branches sum to zero in ST5C AVR model
- V/Hz, PQ, and IG limiters are disabled in ST5C AVR model
- SES (ST5C Supply) is always a value of one
- Kc is equivalent to KID (ST5C Supply)
- SHUNT (ST5C Supply) is always a value of zero
- KSC (ST5C Supply) is always zero

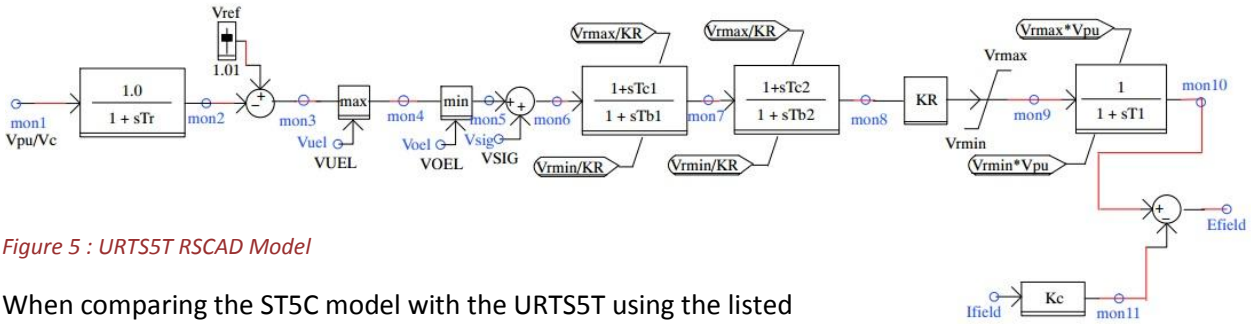

Figure 5 : URTS5T RSCAD Model

When comparing the ST5C model with the URTS5T using the listed assumptions, the two models are very similar. By using the same time constants and gains in the URTS5T, the two models can now be assumed to have, nearly, identical responses for a system. The responses of a generator can now be examined for each model to verify that there has been no critical errors when creating the ST5C model.

5 Verification of Model

The ST5C Model has not been verified to the physical hardware. Figure 5 shows that the system model used to verify the ST5C model behaved as expected of an exciter. The model in figure 5 features two identical generators and two identical dynamic loads, one being controlled by the ST5C the other by the URTS5T. The generator models assume a speed deviation delivered by the slider "DeltaSPEED". In all the following tests the speed deviation was left at zero (modeling a governor with a very fast response).

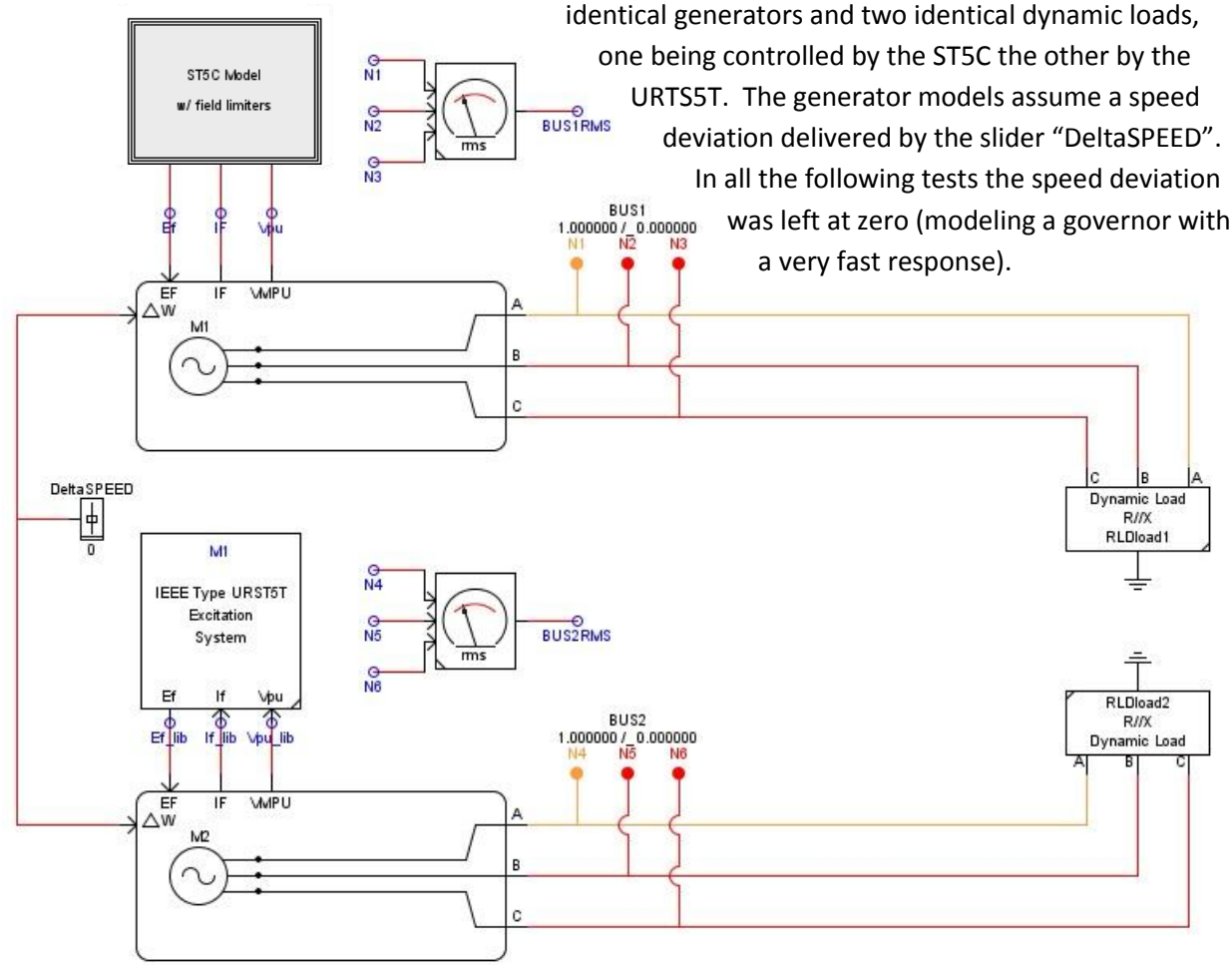

Figure 6: RTDS Exciter Verification Model

Figure 6 shows the RMS terminal voltage of the generators (ST5C left, URTS5T right) as the dynamic load is varied (units are kV). In General the response are the same, however, the ST5C seems to have a faster response and less extreme peaks and valleys.
(Note: The load for the URTS5T was changed just before the ST5C)

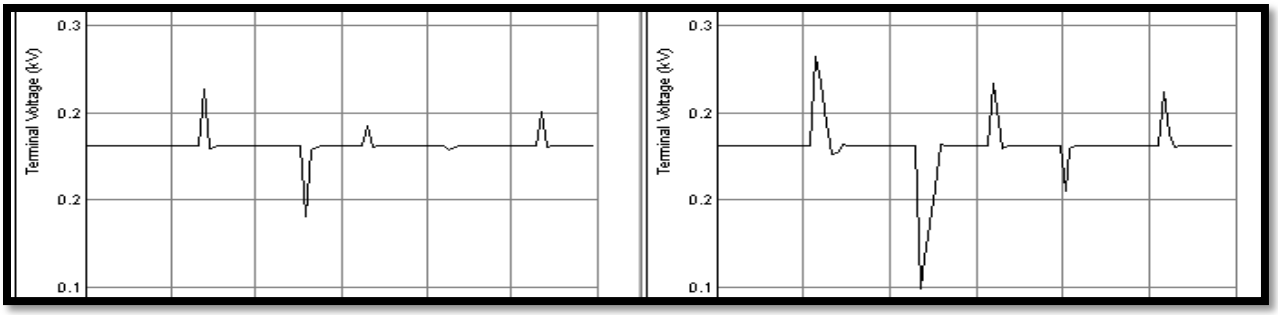

Figure 7: RMS Terminal Voltage

Appendix:

Standard
Simplified Computer Representation for
Power System Stability Studies
UNITROL® 6000

Rev.	-	2008-03-20, Ta	Rev.	C	2010-03-10; MB	Issued: 2010-05-26; MB	Document	Format	Langue	Page	No. of pages
Rev.	A	2008-10-02, MB	Rev.	D	2010-05-26; MB	Check 1: 2010-05-26; MB	ZAB	A4	E	1	27
Rev.	B	2009-04-07, MB	Rev.			Check 2: 2010-05-26; TK					
ABB		Dept. 1 ATPE	Dept. 2	Der.from/Repla.:		Released: 2010-05-26; TK	3BHS223093 E62 Rev. D				
				Replaced by:							